TRANSACTIONS
OF
THE OPTICAL SOCIETY.

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Ordinary Meeting, 8th March, 1917.

Held at Burlington House, London.

F. J. CHESHIRE, F.R.M.S., President, in the Chair.

The following were balloted for, and duly elected to the Society :—

As Members.

MAURICE BLOOD, M.A., F.C.S., F.R.M.S., London.
ALEXANDER EUGEN CONRADY, F.R.A.S., F.R.M.S., London.
E. B. KNOBEL, F.R.A.S., London.
J. H. LEECH, Messrs. WATSON & SONS, High Barnet.
ARTHUR SAMUEL NEWMAN, London.
E. H. SMART, Professor of Mathematics, Birkbeck College.

The undermentioned candidates were proposed for election as Members, the name of the proposer from personal knowledge being appended :—

W. R. ASHDOWN, New Eltham (G. W. Heath).
T. H. BALL, London (Wm. Shackleton).
H. L. BENSKIN, London (C. Lees Curties).
J. C. KIRKMAN, Swansea (G. F. C. Searle).
J. W. MASON, Eltham (G. W. Heath).
G. MIELK, London (C. Hyatt Woolf).
E. L. PARR, London (G. W. Heath).
J. V. RAMSDEN, London (F. J. Cheshire).
J. B. REINER, London (T. Smith).
E. L. VINCENT, London (H. A. Hughes).
R. WIGGLESWORTH, York (F. J. Cheshire).
F. WOOD, Barnsley (F. J. Cheshire).

The following Paper was read :—

A Simple Method of Determining the Size of the Tool required for a given Block of Lenses.

By C. L. REDDING (Northampton Polytechnic Institute).

When it was suggested that I should read the note which I have the honour of submitting to you this evening, I rather felt that it was of too trivial a nature to be of interest to the Members of this Society ; on the other hand, the subject of the blocking up of lenses is an important one, and perhaps more especially at a time like the present, when manufacturers may be asked to supply as rapidly as possible lenses of specified diameters and curves differing appreciably from those which they have been accustomed to produce.

When a new system of lenses has to be worked, it is desirable to choose the best method of blocking each surface, and to make the diameter of the tool equal to the diameter of the complete block.

The size of the tool required for a given block of lenses may be determined by calculation or by previous experience of work of the same general character, but this information may be obtained very easily for any curve, by making use of any concave tool of known radius in the following manner :—

To determine, for example, the size of the tool required to produce lenses of 16 mm. diameter and radius of curvature 32.5 mm., take a concave tool of radius, say, 50 mm., and as nearly as possible a full hemisphere. This tool is $\frac{50}{32.5}$ or 1.54 times larger than the new tool required.

Diameter of finished lens equals 16 mm., allowance for edging, say, 2 mm., and, in addition, the lenses will be blocked not quite touching, say, 2 mm. apart ; thus, on the 32.5 mm. tool a diameter of 20 mm. will be occupied by each lens with allowances.

To obtain the diameter of the disc which will cover the same fraction of a tool of 50 mm. radius, as the 20 mm. diameter would on a tool of 32.5 mm. radius, we multiply 20 by $1.54 = 30.8$; in other words, discs of 30.8 mm. diameter on a tool of 50 mm. radius are equivalent to discs of 20 mm. diameter on a tool of 32.5 mm. radius.

If thin circular discs of 30.8 mm. diameter are cut out and placed inside the 50 mm. tool, we can note :—

(1) The best method of blocking.
(2) The number of lenses that can be blocked.
(3) What diameter, or what depth, of the 50 mm. tool is being used.

The same number of discs of 20 mm. diameter could be placed on the 32.5 mm. tool, and the corresponding blocks would be of the same general character.

To obtain the diameter (or depth) required for the 32.5 mm. tool, the useful diameter (or depth) of the 50 mm. is divided by 1.54.

It is better to determine the " depth " if the tool is to be nearly a full hemisphere, while the " diameter " should be specified when the tool is to be a shallow one.

This method of working may be used also to determine the maximum allowance available for edging and separation, when the lenses have to be " squeezed " in order to make a satisfactory block; if this allowance works out to be small, it may be advisable or necessary to roll or rough edge the glass before the lenses are blocked up.

Table Giving Maximum Diameters (mm.) Available for each Lens Plus Allowances on a Hemispherical Tool of 50 mm. Radius when the Number of the Block is Specified.

Hemispherical tool 50 mm. radius.		Diameters available in millimetres	
Number of lenses in Block.	Character of Block.	Disc Method.	By Calculation.
3.	Ring 3.	65·5	64·45
4.	Ring 4.	58 bare	57·7
5.	Ring 5.	50·5	50·7
6.	Ring 5 Centre 1.	50	50·
7.	Ring 6 Centre 1.	44·5	44·7
8.	Ring 7 Centre 1.	40 bare	39·8
10.	R. 7 R. 3.	37 bare	36·8
11.	R. 8 R. 3.	35·5	35·7
12.	R. 8 R. 4.	34·5	34·6
14.	R. 9 R. 5.	32·5	32·3
15.	R. 9 R. 5. C 1.	31 bare	30·9
16.	R. 9 R. 6. C. 1.	30	30·2
17.	R. 10 R. 6. C. 1.	29·5	29·5
18.	R. 10 R. 7. C. 1.	28	28·3
19.	R. 11 R. 7. C. 1.	27	27·1
20.	R. 11 R. 8. C. 1.	26·5	26·5
21.	R. 12 R. 9. C. 3.	25	25·1

For curves of longer or shorter radius than 50 mm., multiply or divide the diameters in table by " ratio constant." The factors underlined in column two, decide the character of the block.

Numerical Examples.

(1) What is the allowance available for edging and blocking if lenses of diameter 13 mm. and radius 11.4 mm. are required?

$$\frac{50}{11{\cdot}4} \times 65{\cdot}5 \text{ mm.} = 15 \text{ mm.},$$

thus working three in a block on a hemispherical tool the allowance available would be 2 mm., *i.e.*, 15 mm. minus the finished diameter.

(2) Lenses of finished diameter 19 mm. and radius 37.5 mm. are required, how many can be blocked on a hemispherical tool? Adding 2 mm. to the diameter for edging, &c., we have :—

$$\frac{50}{37{\cdot}5} \times 21 \text{ mm.} = 28 \text{ mm.};$$

and on reference to the table we find that 18 lenses can be blocked, ten in the outer ring, seven in the middle ring and one in the centre.

If an allowance of 3 mm. were necessary for edging, &c., the lenses could be worked 17 in a block (R. 10., R. 6., C1.).

This method of working first occurred to me while I was discussing with Mr. S. D. Chalmers the best way of explaining to the workers in the Optical Munition Training School, how to determine the diameter of the tool required for a given block of lenses; at the time, it was necessary to devise some means of making the calculation as simple as possible, and I desire to express my very best thanks to Mr. Chalmers for his suggestions.

I do not suggest that the method I have described will be employed by anyone having experience of a variety of work, nor by the calculator who can obtain the results mathematically, but even in these cases the disc method may be usefully employed to check results; from a workshop point of view it certainly has the advantage of being simple and practical.

DISCUSSION

On "A Simple Method of Determining the Size of Tool Required for a given Block of Lenses."

Mr. P. F. Everitt said that, in connection with the subject dealt with by Mr. Redding, he had been some years ago interested in the problem which, in that case, took a slightly different form. The question was, to determine the diameter of blocks of three, four, or more lenses of equal diameter. He had not then had the advantage of the tables which Mr. Redding had now worked out, so, of course, he had used the direct method of calculation. In many cases Mr. Redding's arrangement was excellent, and could not be surpassed for workshop use, but from the point of view of the designer it was a different matter; so much time would have to be spent in cutting out discs that anyone accustomed to such work could tackle the problem more expeditiously on paper. He proposed, therefore, to give the exact formula, as it might be useful to some of the younger members.

The diagram Fig. 1 represents a block of three lenses, and Fig. 2 a section of the block through one lens.

R is the radius of the tool, and d the effective diameter of the lens, *i.e.*, the true diameter plus the allowance for edging and clearance allowance

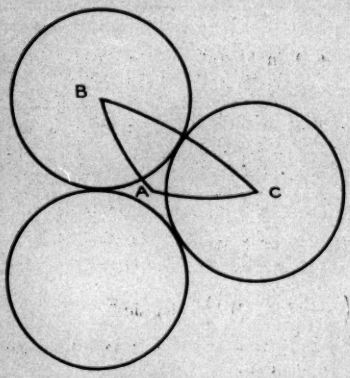


FIG. 1.

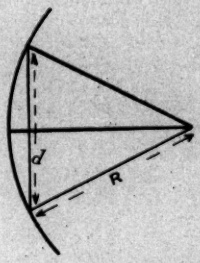


FIG. 2.

when the block is made up, while n is the number of lenses in the circle. Calling the centre of the block A, the centres of two adjacent lenses B and C, solving the spherical triangle A B C, and calling θ the angular diameter of the block, it is easily shown that

$$\theta = 2\left[\sin^{-1}\frac{d}{2\,\mathrm{R}\sin\frac{\pi}{n}} + \sin^{-1}\frac{d}{2\,\mathrm{R}}\right]$$

This general formula reduces to following forms for different values of n:

Block of 3.	$n = 3$	$\theta = 2\left[\sin^{-1}\frac{d}{\mathrm{R}\sqrt{3}} + \sin^{-1}\frac{d}{2\,\mathrm{R}}\right]$
,, 4.	$n = 4$	$\theta = 2\left[\sin^{-1}\frac{d}{\mathrm{R}\sqrt{2}} + \sin^{-1}\frac{d}{2\,\mathrm{R}}\right]$
,, 7.	$n = 6$	$\theta = 2\left[\sin^{-1}\frac{d}{\mathrm{R}} + \sin^{-1}\frac{d}{2\,\mathrm{R}}\right]$
,, 14.	$n = 10$	$\theta = 2\left[\sin^{-1}\frac{d}{\mathrm{R}\sqrt{2}} + 3\sin^{-1}\frac{d}{2\,\mathrm{R}}\right]$

Mr. S. D. Chalmers said that the calculated values in Mr. Redding's tables had been calculated by means of similar formulæ to those referred to by Mr. Everitt, but in the course of their calculation one interesting question had arisen. It was desired to find the maximum diameter lenses which would go in a given ring on the tool.

The formula was—

$$\sin^{-1}\frac{\frac{d}{2r}}{\sin\frac{\pi}{n}} + (2m+1)\sin^{-1}\frac{d}{2r} = \frac{\pi}{2}$$

where d is the diameter, r the radius of curvature, n the number in the ring, and m=0, 1, 2, for the outside 2nd and 3rd rings (counting from the outside ring).

Denoting $\sin^{-1}\frac{d}{2r}$ by A :—

$$\frac{\sin A}{\sin\frac{\pi}{n}} = \sin\frac{\pi}{2} - (2m+1)A$$

$$\text{or } \log\sin A - \log\sin\left(\frac{\pi}{2} - (2m+1)A\right) = \log\sin\frac{\pi}{n}$$

The best method of solving this is by trial and error; take the case of m = 1 and n = 6 as a rough approximation.

$$A = \tfrac{1}{3}(90^\circ - 3A)$$

or $A = 18^\circ$ approx.

			Prop. part.
L sin A = L sin 18° =	9·48998	pr 1′	38,86
L sin 90° − 3A L sin 36° =	9·76922	pr 1′	3 × 17,38
	$\bar{1}$·72076	diff. pr 1′	= 91,0
log sin 30° =	$\bar{1}$·69897		
diff. =	·02179		
L sin 17° 36′ =	9·48054		39,81
L sin 37° 12′	9·78147		16,64
	·69907		89,73
	·69897		
	10		

giving A=17° 36′ to the nearest minute, or 17° 35′ 53″ if this accuracy were required.

The value of A, correct enough for the present purpose, should usually be obtained on the second trial.

MR. T. SMITH said that, as one who had not been concerned with this problem, it struck him as rather remarkable that a question of such practical importance had never been worked out, and the results tabulated once and for all. Mr. Redding's method of cutting out discs and pasting them in the bowl seemed to be a very simple and satisfactory one, and one which showed very clearly the advantages that different arrangements would have; but it would probably be very valuable if Mr. Redding would carry his work a little farther, and compile tables so that it would only be necessary simply to refer to them. The form those tables might take would be this. It was obvious that the only quantities they were concerned with were the ratio of the diameter of the discs, including allowances, to the radius of the bowl, and the angular aperture of the bowl. If a series of values were taken for that ratio, the table could show the most advantageous arrangements with different numbers of discs. It would be found, for instance, for some definite value of that ratio that, in the first place, obviously the simplest case was where only one disc was being worked. If that ratio were of suitable magnitude, it would be possible to go a step farther, and in the next ring, assuming there was only to be a centre in one ring, it would be possible to use, it might be, in some cases, three outer discs, in some cases it might be four, in some cases it might be five. It just depended upon that ratio how many could be got in. And going to the next stage, there would be another number which could be worked with a definite increase in the aperture of the bowl. It was quite clear that when one came to large numbers of discs, each successive increase in the size of the bowl would enable a considerable extra number of discs to be worked, so that all practical cases would be exhausted by tabulating only a small number of figures. For example, when the curvatures were very small, the arrangements adopted would be those suitable for flat surfaces, with the discs arranged on the hexagonal principle with nuclei of either one or three. In the former case the increments would always be multiples of six, so that the smallest tool would take one disc; the next size would suffice for seven, the next for thirteen, and so on; the point of missing out the intervening numbers being that as large a tool was required to get in eight as to get in thirteen. In connection particularly with small curvatures, it would be convenient to add a column giving the ratio of the diameter of the disc to the aperture of the tool. He thought if the problem were tackled on those lines, and the table published for a set of values of the fundamental ratio, the problem would be completely solved, and it would be an exceedingly valuable table to have published, and one which should find a ready sale. He did not know whether Mr. Redding would be prepared to undertake to add to his work in that way, but it appeared to be well worth doing, especially if it included a description of the way in which the block should be made up, such as a ring of 9, a ring of 5, and a centre of 1.

A Variable Angle Collimator.

By T. F. CONNOLLY, M.Sc.

A collimator consists essentially of a good telescope object glass with a webbed or other diaphragm fixed in the "solar focus." The emergent rays for any point on the diaphragm are rendered parallel by the object glass, and the collimator thus conveniently takes the place of a fiducial mark or marks at an infinite distance.

The instrument to be described differs from an ordinary collimator in having a biprism introduced between the webbed diaphragm and the object glass. With a suitably oriented biprism the effect is to produce two separate images of the central wire, which images are collimated by the object glass as though they were real wires. The biprism is mounted in a short tube, which, sliding within the collimator body, not only produces two wire images, but also varies the distance between the images as it slides along. This movement is given by means of a knob projecting through a long slot in the collimator tube.

The biprism in the above could be replaced by either a Rochon or a Wollaston prism, but these would show little advantage and are much more costly.

The above use of double image prisms is believed to be novel, though their use in a converging or parallel beam is well known. In Figs. 1 and 2,

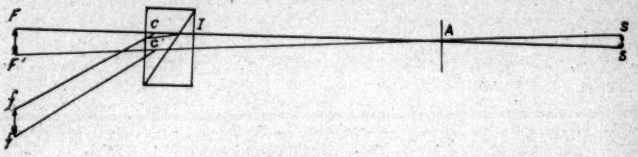


FIG. 1.

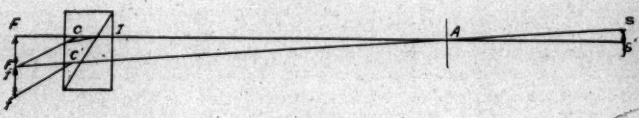


FIG. 2.

extracted from Biot, Precis de Physique Tome II, 1817, image sizes are being measured by such a contrivance.

The Measurement or Checking of Small Angular Intervals.

The above instrument provides a collimated system which gives a continuous variation in the angular separation of the two wires. If one edge of the slot is calibrated to correspond with this separation, a convenient standard of angular measurement is available. An immediate and important use for such a standard is in connection with marking off or checking of stadia intervals in levels or theodolites, and for checking the spacing of the rulings in prism binoculars.

In the experimental instrument as actually constructed, a 1.7 inch object glass of 15 inches focal length is used, and a 10 inch traverse can be given to the biprism (angle approximately 4 deg.). In this system the apparent angular separation of the wires varies from 20 minutes of arc

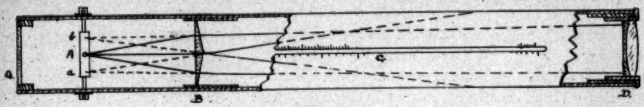


FIG. 3.

to just over 3 deg. A diagrammatic section of the instrument is shown in Fig. 3. If the instrument is to be used exclusively as a collimator of variable angle for checking stadia diaphragms, a range of angular values from 10 minutes to over 1 deg. would be more suitable. This is most conveniently done by using a biprism of smaller angle.

Use of the Instrument as a Focometer.

If a lens, or any optical system forming a real image, is introduced into the parallel rays emerging from the collimator, real images of the

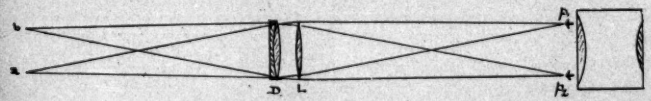


FIG. 4.

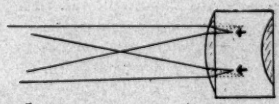


FIG. 5.

wires are formed. By sliding the biprism along the tube the distances apart of these images may be varied so as to coincide (Fig. 6) with two

pointers in an observing eyepiece. This eyepiece system may be of either the Ramsden (positive) or Huyghenian (negative) types (Figs. 4 and 5). The latter type has the advantage of having the pointer inside the optical system, and also shortens the overall length of the instrument. It is important, before adjusting the separation, that the collimator wires be carefully focussed by moving the eyepiece so that their images are exactly in the plane of the pointers. The parallax test for this adjustment gives good results, and is recommended.

After having carefully focussed the crosswires and adjusted their separation as above, the position of the biprism is a function of the *true focal length* or *true dioptres* of the lens or system under examination. One edge of the slot may be calibrated to show either of these values.

FIG. 6.

Under experimental conditions, results consistent within 0.1 Dioptre (one tenth dioptre) have been obtained with powers varying from 2D to 10D. The slot, however, is long enough to allow calibration up to 20D. This accuracy is ample for all ordinary use in the case of spectacle and most other lenses.

The instrument is still in its experimental stage, and hopes are entertained that, with some modifications (such as an achromatic biprism, &c.) it will be found capable of giving results much closer than the above, and of very considerable precision.

For generous and continued assistance in the above work I am indebted to Mr. W. Shackleton, F.R.A.S., and I must also express my thanks to Mr. S. W. Morrison, of the Ministry of Munitions, for his help and for opportune aid in erecting the apparatus for demonstration.

DISCUSSION

On "A Variable Angle Collimator and Its Application to the Determination of the Focal Lengths of Spectacle and other Lenses."

MR. S. D. CHALMERS said he did not see why Mr. Connolly had found it necessary to use a bi-prism. He thought in cases of that sort it would be sufficient to use a simple prism covering half the lens, and to use a direct beam in the other case. In that way he thought very much greater accuracy of focussing would be obtained than by using the edge of the bi-prism to split the field into two halves and throwing two beams across one another. He had had some experience in measuring focal lenses by a device somewhat similar to that of Mr. Connolly, but without the variable separation of the images; he had placed a prism in front of the collimator and used half the collimator for the direct beam and half for

the edge beam. He had found it a very great advantage, indeed, to have the focus on the axis undisturbed. Half the collimator gave the axial beam, and he was able to determine the right focal position more accurately than when both beams were displaced. He had found it essential in that particular case also to screen the aperture with a monochromatic screen. If the prism were adjusted so that the deviation was a simple number, it was possible to obtain a fairly correct focal length of the lens without calculation.

Dr. Reginald S. Clay thought Mr Connolly's was a very pretty method, and it was obviously one which could very easily be applied. If one wished to make the instrument more simply, the whole apparatus might be carried in a V, which might be made of two pieces of wood. If the eyepiece was mounted in a tube of the same size as the collimator, it would always be in line with the collimator. The eyepiece could be put at the end of the V, and the collimator moved for the preliminary focussing; a slight movement of the eyepiece would then give the necessary final adjustment. The accuracy required for the focussing might be eliminated to a large extent if the lens which was being measured were put at approximately its focal length from the collimator.

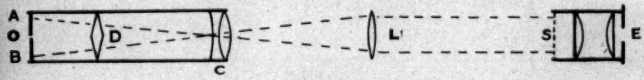


Fig. 7.

A B C, Collimator; D, Biprism; L, Lens to be tested; E, Eyepiece; O, Slit; A and B, Images of Slit formed by the Biprism; S, Scale in Eyepiece.

This would be known or could be found by a preliminary experiment. Then the beams which were entering it from each of the two images A and B of the collimator slit would cross at the front focal point of the lens, which will be at C, and so far as these two points are concerned the size of the image would be approximately the same, even if the eyepiece were not placed exactly at the right distance, and the effect of an error in focussing would be eliminated. It was quite possible—it could not be said without trying—however, that this might not give a good result on account of the aberration of the lenses. The method seemed to him a delightful one, and one which could be so quickly and readily applied that he thought the first thing he should do would be to go home and make a similar instrument.

Mr. T. Smith agreed with Dr. Clay that the apparatus was a very convenient and compact one. He did not, however, gather from Mr. Connolly's remarks what was the kind of accuracy at which he was aiming. If seemed to him that the apparatus as shown was not quite suitable for

work really demanding considerable accuracy, but that it could be made so if the Huygenian eyepiece was abandoned and a Ramsden eyepiece substituted. With the Huygenian eyepiece as it stood, Dr. Clay's suggestion was incorrect.

DR. CLAY (interposing) said he quite agreed that his suggestion did not apply to the Huygenian eyepiece.

MR. T. SMITH said the accuracy of the arrangement as it stood depended entirely on the accuracy with which it was possible to focus, and errors due to imperfect focussing were only eliminated for one particular focal length of the lens under test. Whether that was in practice a serious matter or not Mr. Connolly would no doubt be able to say, but by putting in place of the Huygenian eyepiece a Ramsden, and adopting the suggestion which Dr. Clay had put forward, that source of error would disappear.

THE PRESIDENT pointed out that in his opinion there was one serious objection to the apparatus. What Mr. Conolly was doing, so far as he understood it, was to measure the equivalent focal-length of a system which consisted of the lens being tested combined with the field-lens of the eyepiece. In order, therefore, that the focal-length, or power, of the lens being tested should be determined it would be necessary to employ a positive and not a negative eyepiece.

Let f_1 = the focal-length of the lens being tested, and f_2 that of the field-lens of the Huygenian eyepiece employed. Further, let d = the distance of the field-lens, inside the focus of the lens being tested, when the measurement is made, and f the focal-length of the combination of the lens being tested and the field-lens of the eyepiece; then the following relationship obtains :—

$$\frac{1}{f} = \frac{1}{f_1}\left(1 - \frac{d}{f_2}\right)$$

i.e., the focal-power of the lens being tested is equal to the focal-power of the combination multiplied by a constant.

The negative eyepiece must necessarily introduce a serious error, and further. It was important to bear in mind that what was wanted in the case of spectacle lenses was not the equivalent focal-length but the back focal-length.

The function of a spectacle lens is to project an image of an external object into the plane of the far-point of the eye. It did not matter what the focal-length was so long as the lens employed projected the image of the external object into the plane of the far-point. That had been pointed out of late years in Germany in connection with the cataract glasses made by the firm of Carl Zeiss, with one aspherical surface, which gave a field of view of something like 50 deg.

This firm invented a focometer for that particular work which measured, not the equivalent focal-length, but the back focal-length in every case. Then, having got the back focal-length, it was only necessary to ensure in fitting them to spectacles that there was a certain distance between the vertex of the lens and the vertex of the cornea to ensure that an image of the object was projected into the plane of the far-point. Apart from that, he thought the apparatus was very ingenious, and would serve as a very useful and suggestive addition to their stock of optical devices.

Mr. Connolly's Reply.

MR. CONNOLLY said he would deal first with the President's remarks. He cordially agreed with all that the President had said about the value of the back focal-length; only, unfortunately, he (Mr. Connolly) had been dealing with facts as he found them. That was to say, he had been dealing with the normal test-case, and the Optical Society's standards which were founded on the equi-convex system and on true focal-lengths. If the determination of the back focal-length was needful, a modification could be introduced.

The use of the instrument was not limited to spectacle lenses, and it was primarily designed to measure true and not back focal-lengths.

He was afraid that he must disagree with the President's statement that "the negative eyepiece must necessarily introduce a serious error." Confining the discussion to first order theory, the negative eyepiece is guiltless of causing any error at all in the final result. In the President's own words, resulting from the formula quoted, "the focal power of the lens being tested is equal to the focal power of the combination *multiplied by a constant*." The multiplication by a constant only means a shifting of the scale in the initial calibration, and is made with ease. It is not necessary but merely more convenient to use a negative eyepiece, and there is no resulting error.

MR. S. D. CHALMERS, interposing, said the eyepiece would always magnify the image the same number of times, and that magnification was allowed for in calibration. The field lens of the eyepiece would magnify the image, and, therefore, apparently magnify the focal length, but this magnification was always the same, and was eliminated by empirical calibration.

MR. CONNOLLY. Quite so.

In continuing, Mr. CONNOLLY said Dr. Clay's suggestion was excellent —a sort of telecentric system—but it had one practical disadvantage, that it increased the length of the whole system. If a 2D lens of 20 ins. focal-length was under examination, it was becoming a cumbersome instrument. The suggestion had been thought of, but neglected for the

simple reason of securing compactness; and the errors of focus were, in fact, not serious.

The suggestions of Mr. Chalmers were interesting and of considerable value, but could not be embodied conveniently in the present variable angle instrument.

The value of a bi-prism, as against a single prism, is that any specified separation is obtained with a prism angle only half as large and consequently with much smaller chromatic and other aberrations.

A paper "On the Design and Testing of Telescope Objectives," by P. F. Everitt, B.Sc., was also partly read, but in consequence of restriction of time it was necessary to postpone the discussion until the May meeting. In order, therefore, to present the paper to members of the Society in a complete form, it will appear in the May number of the *Transactions*, together with the discussion and other remarks upon it which have been communicated in writing.

ABSTRACTS.

"Double Refraction in Metallic Films by Kathode Volatilisation," by Carl Bergholm. (Dissertation, Upsala, 1915. Abstract by H. Krüss. ZEIT. FÜR INSTR. 36, pp. 278-279, 1916.)

Having reviewed the history of the double refraction displayed by such films, the author develops the theory of the half-shade compensator of Brace, because the double refraction of Brace gratings is of the same nature. In this instrument the compensator, a mica plate, is between the two crossed nicols, and between the compensator and polariser is introduced a small strip of mica so as to take up the middle of the reel; the compensator can be turned, and at a certain position all the parts of the field will appear of the same brightness. This uniformity is disturbed by the interposition of any doubly-refracting plate between the polariser and compensator; uniformity is restored by rotating the compensator, and from the angle the phase difference produced is estimated. As in the instrument of Brace, the mica strip, 0·001 mm. in thickness and perfectly plane parallel, is embedded in Canada balsam between two cover glasses. The apparatus can be used in various ways. Maximum brightness being desirable, different methods may be advisable for different ranges of phase difference. The methods are not all equally accurate, however. The author further experimented on the best methods

of obtaining well-adhering metal films on glass by kathode volatilisation. The glass plate should be at right angles to the plane of the kathode foil and the angle of incidence of the particles projected by the kathode should be large. In order to investigate the nature of the double refraction, the author scratched metal films—not doubly refractive—with the aid of a paint-brush or emery powder; such films then showed double refraction, and it resulted that the component vibrating parallel to the lines produced was always of higher velocity than the component at right angles to the lines. This was so for all the metals; but the absolute values of phase and of amplitude effect depended upon the metal. The double refraction in the kathode films, experiments prove, is due to ultramicroscopic grooves in the film, produced apparently in the following way:—The volatilised metal first condenses in a uniform thin film; the particles following afterwards plough furrows in the film, the furrows indicating the tracks of the particles and corresponding to the scratched lines in ordinary films. H. B.

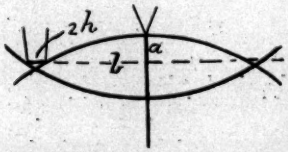
"COMBINATION OF A JAMIN REFRACTOMETER WITH A SPECTROPHOTOMETER." By N. Posejpal. (ANNAL. PHYSIK, 49, pp. 417-433, 1916.)

Since the use of an interferometer and a simple telescope only admits of reading within 0.1 of the width of a fringe, which is insufficient for many purposes, and since the use of a spectroscope and other combinations does not offer real advantages, the author tried the combination of his Jamin refractometer with a Lummer Brodhun spectrophotometer for measuring refraction and dispersion, and he is going to adopt this method for the optical study of gases at reduced pressure. Whilst in a spectroscope with eye-piece observation the adjustment for the interference minimum has to be made with reference to the neighbouring parts of the spectrum, the eye of the observer is brought up to the image in the case of the spectrophotometer; the illumination of the objective is monochromatic, and the brightness of the neighbouring parts does not enter. The spectrophotometer thus acts like a monochromator. The author convinced himself by experiments that a high sensitiveness is realised, which will be the greater the higher the brightness of the slit, which is parallel to the fringes and the more uniform this brightness of the slit. For this reason, the author arranges that the slit is in the real plane of the image, *i.e.*, in the focal plane of the convex lens, which receives the light from the refractometer. The illumination, by means of a 100-candle Nernst lamp, is by the aid of mirrors and lenses also thrown on the comparison slit, in front of which a screen of opal glass is placed. Details are given of the author's experiments with his Jamin compensator. With sufficient width of the slit, not less than 0.013 mm., the mean error of a measurement amounted to 1.1 per cent.; with narrower slits the

error became much greater, 5.5 per cent. for 0.002 mm., because of the small light intensity. It is noteworthy that the field was never quite uniformly dark with the minimum adjustment, probably because the planes of the refractometer were not perfect, and the fringes hence slightly curved. Two methods of using the combination are discussed. In practice all temperature fluctuations and also all concussions must carefully be avoided. The author therefore worked at Prague, Bohemia, only when there was no wind and at night time when the temperature fluctuations did not exceed 0.5°C. Then the mean error of an observation was less than 1 per cent., equivalent to 0·06 per cent. of the quantity to be determined. H. B.

"SPHEROMETER WITH WORN FEET." (ENG. MECH., Jan. 19, 1917, p. 511.)

Prof. C. V. BOYS, writing in reply to a query respecting the effect of worn spherometer feet in determinig the radius of curvature of convex and concave surfaces, first discusses the formulæ for spherometers with pointed and ball feet respectively. He then goes on to say, "if in the case of a spherometer with pointed feet these have worn so as to show flats of appreciable size so that the width of the flat in a radial direction is $2h$, as shown in the Figure, then it will be clear that the ordinary formula $R = \frac{a^2 + b^2}{2a}$ for the pointed toe spherometer must be altered to read $R = \frac{a^2 + (b \pm h)^2}{2a}$ and a true result will be obtained. The negative sign is to be employed for a convex and the + sign for a concave surface.



W. S.

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